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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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PUERTO RICO DEPARTMENT OF NATURAL AND ENVIROMENTAL RESOURCES

SCIENTIFIC INVESTIGATIONS MAP 2008-3030
Potentiometric surface of the upper and lower aquifers of the North Coast Limestone aquifer system and hydrologic conditions in the Arecibo-Manatí area, Puerto Rico, November 27-December 1, 2006
PLATE 1 of 2

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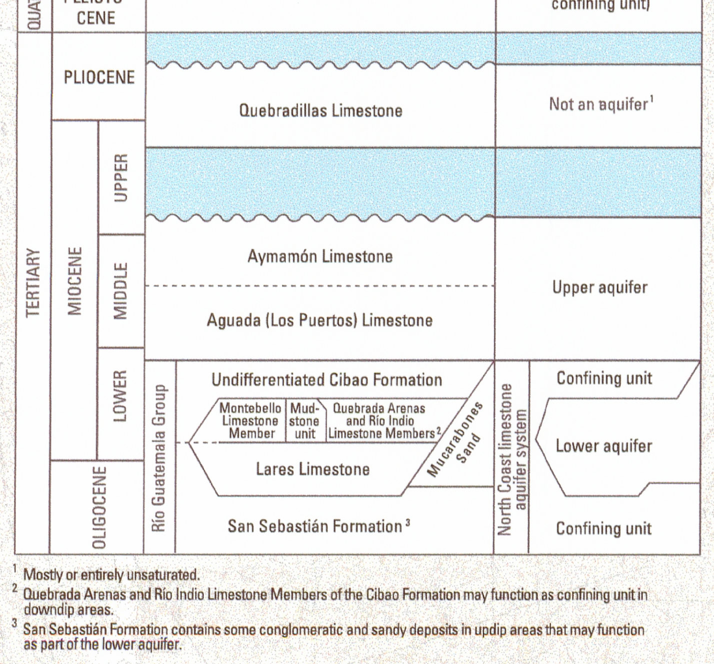
Introduction

A ground-water level synoptic survey of the limestone aquifer in the Arecibo to Manatí area, Puerto Rico, was conducted from November 27 through December 1, 2006 by the U.S. Geological Survey in cooperation with the Puerto Rico Department of Natural and Environmental Resources. The purpose of the study was to define the spatial distribution of the potentiometric surface of the upper and lower aquifers of the North Coast limestone aquifer system. A potentiometric surface is defined as an areal representation of the levels to which water would rise in tightly cased wells open to an aquifer (Fetter, 1988). These potentiometric surface maps can be used by water-resources planners to understand the general direction of ground-water flow and to evaluate ground-water conditions for water supply and resource protection. The study was conducted during a period of rising ground-water levels resulting from above-normal rainfall during October and November 2006 when rainfall amount was about 30 percent above normal. The study area encompassed 125 square miles and was bounded to the north by the Atlantic Ocean, to the south by the southern extension of the limestone units, to the west by the Río Grande de Arecibo, and to the east by the Río Grande de Manatí (pls. 1 and 2; inset).



¹ Mostly or entirely unsaturated.
² Quebrada Arenas and Río Indio Limestone Members of the Cibao Formation may function as confining unit in downdip areas.
³ San Sebastián Formation contains some conglomeratic and sandy deposits in updip areas that may function as part of the lower aquifer.

Figure 1. Stratigraphic and hydrogeologic units of the North Coast Ground Water Province of Puerto Rico (modified from Renken, 2002).

North Coast Limestone Aquifer System

The upper aquifer in the Arecibo to Manatí area is made up of carbonate strata that are part of the Aymamón Limestone and the underlying Aguada (Los Puertos) Limestone (fig. 1) (Renken and others, 2002). Ground water within the upper aquifer is mostly under unconfined conditions, and confined conditions are only present where the aquifer extends beneath poorly permeable, clayey sand, silt, clay, and clayey mud (Renken and others, 2002).

The lower aquifer includes the Montebello Limestone Member of the Cibao Formation and the Lares Limestone (Renken and others, 2002). The San Sebastian Formation, beneath the Lares Limestone, confines the aquifer at its base. Ground water within the lower aquifer occurs under confined and unconfined conditions. Unconfined conditions occur where the principal carbonate-rock units that make up the aquifer crop out or lie in the shallow subsurface. Confined conditions occur in areas where the aquifer extends northward and dips beneath the undifferentiated Cibao Formation, which acts as a confining unit (Renken and others, 2002). In the study area, the confinement of the lower aquifer begins between latitudes 18°24' and 18°25' (pl. 2). The two northward flowing rivers, the Río Grande de Arecibo and the Río Grande de Manatí, were deeply incised during the low sea levels stands in the Pleistocene, breaching parts of the middle confining unit and even into the lower aquifer. These valleys were replaced with alluvial deposits, which are generally permeable.

Hydrologic Conditions

Measurements of ground-water levels at existing wells, continuous recorded ground-water levels at observation wells, daily rainfall, and streamflow discharge were used to describe the hydrologic conditions in the study area during the synoptic survey. The hydrologic conditions during the study can be considered as representative of a period of above normal rainfall.

Ground-water levels

Ground-water level measurements taken at existing wells were used to prepare the potentiometric-surface maps of the upper aquifer (pl.1) and lower aquifer (pl. 2). The ground-water level synoptic survey included measurements in 20 wells for the upper aquifer and 24 wells for the lower aquifer. Ground-water level measurements were taken at wells that were either not pumping or wells that were shutdown for a brief period during the survey. In the latter case, a recovery period of 30 minutes allowed the drawdown in the well to achieve a near static level representative of the aquifer at the measurement point. The 30-minute recovery period prior to obtaining a water-level measurement at pumping production wells was adopted as a standard procedure. During synoptic studies, it is not possible to stop pumping at most active wells for the amount of time (hours to days) necessary to obtain a static ground-water level. Thus, the water level reported for active production wells is lower than the water level in the aquifer in the general vicinity of the well. However, the 30-minute period can enable future investigators to compare water levels reported under such time constraint conditions with water levels with a longer recovery period at each well. Land-surface altitudes from the U.S. Geological Survey (USGS) 1:20,000 scale topographic maps (Arecibo, Barceloneta, Ciales, Florida, Manatí, and Utuado) were used to reference ground-water levels to the local mean sea level datum. In addition to the ground-water level measurements, the potentiometric surface contours were delineated and adjusted using hydrologic features such as springs, gaining and losing stream reaches, and aquifer drawdown effects in the vicinity of well fields.

The survey was conducted after a period of above-normal rainfall. Cumulative rainfall during 2006, was recorded at three rainfall stations in the area (table 1). The stations are: the USGS San Agustin raingage (182328066423500) (pl. 2), the USGS Río Grande de Manatí at Highway 2 (50038100), and the National Weather Service (NWS) Manatí 2E (665807). Table 1 also includes the monthly normals and departures from normal at NWS Manatí 2E station, which were exceeded in 8 months during 2006 and was about 30 percent above normal during October and November 2006.

Long-term ground-water levels in the USGS observation wells Tiburones (182626066345100, upper aquifer)(pl.1) and Cruce Dávila NC-5 (182544066341500, confined part of lower aquifer)(pl. 2), both located in Barceloneta, and Florida 1 (182209066340600, unconfined part of the lower aquifer)(pl. 2) located in Florida, are shown in figure 2. Water levels in the Cruce Dávila area near the town of Barceloneta have decreased since the late 1960s, when the first artesian wells were drilled. The documented water-level data at the USGS Cruce Dávila NC-5 observation well indicate that ground-water levels have declined more than 100 feet from 1989 to 2004 (fig. 2B). A slight increase in aquifer head was observed during 2006, and can be ascribed primarily to a wetter than normal rainfall period during 2005 and throughout 2006. Ground-water levels at the USGS observation wells Florida 1 and Tiburones, from November 1 through December 15, 2006, are presented in figure 3A and B, respectively. Water levels in these observation wells increased by 4 and 0.3 feet, respectively, in response to rainfall events prior to and during the synoptic ground-water level survey (fig. 3A and B). The areal impact of rainfall is evident in the mean daily streamflow discharge at USGS gaging station 50038100, Río Grande de Manatí at Highway 2 (fig. 4).

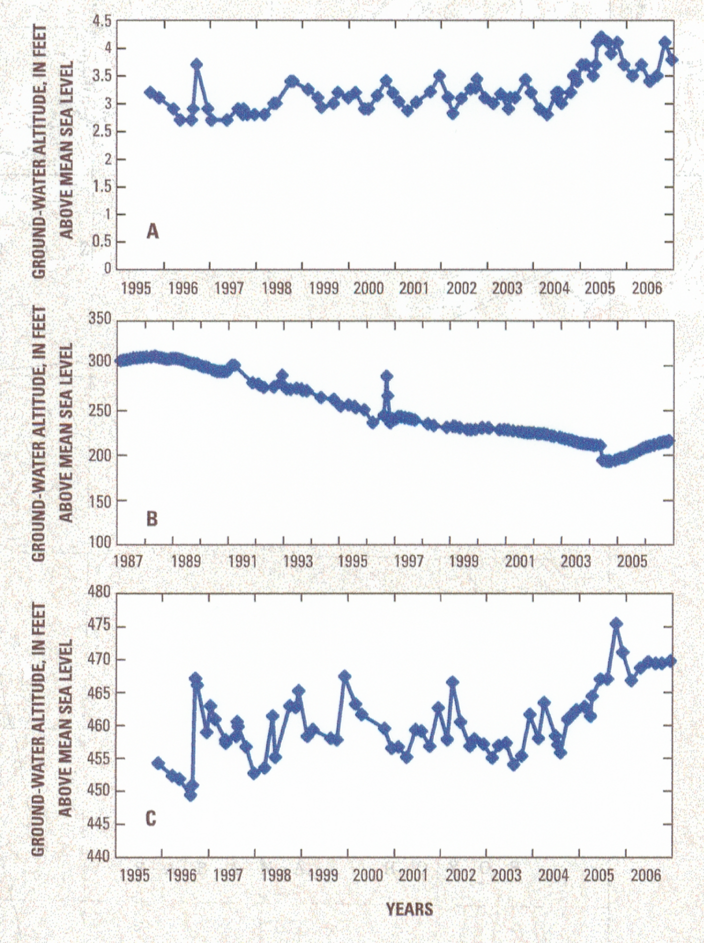


Figure 2. Long-term ground-water levels in the (A) Tiburones, (B) Cruce Dávila NC-5, and (C) Florida 1 observation wells.

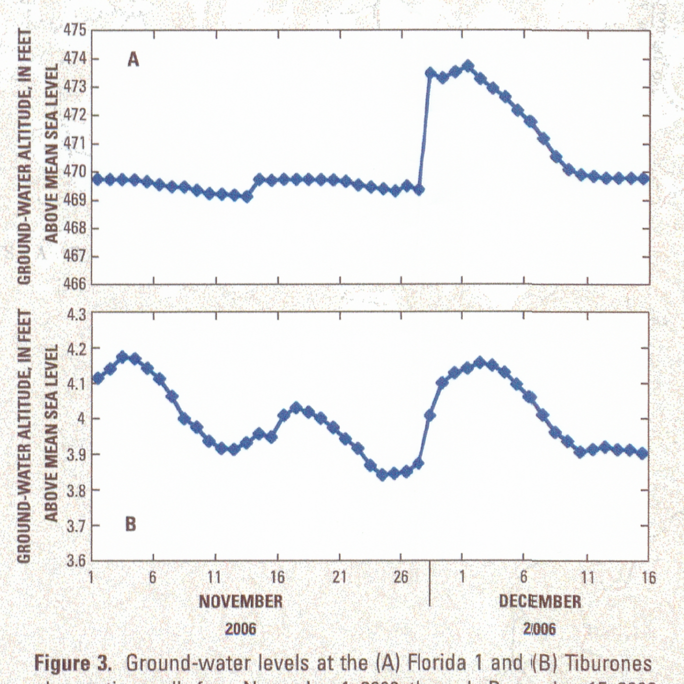


Figure 3. Ground-water levels at the (A) Florida 1 and (B) Tiburones observation wells from November 1, 2006, through December 15, 2006.

Ground-water flow

The general direction of ground-water flow is indicated on the maps by flow lines drawn perpendicular to the potentiometric surface contours on plates 1 and 2. The direction of ground-water flow in the upper aquifer is generally northward; however, in the eastern and western parts of the study area, the flow is towards the alluvial valleys of the two rivers. Potentiometric surface contours of the upper aquifer curve upstream in the stream valleys, denoting areas of gaining stream reaches. Contours less than 10 feet were not delineated, due to the uncertainty of land-surface altitude. Ground-water levels ranged from about mean sea level to 29 feet in the upper aquifer during the synoptic survey. South of the 20-foot contour shown for the upper aquifer on plate 1, ground-water flow occurred primarily as sheet flow along the top of the Cibao Formation, which forms the confining unit between the upper and the lower aquifer (fig. 1).

Ground-water in the lower aquifer generally flows northward towards the two cones of depression and eastward and westward to the Río Grande de Manatí and the Río Grande de Arecibo (pl. 2). In the west-central part of the study area, where no significant cones of depression were evident, ground-water flow from the unconfined area of the lower aquifer may overflow northward over the Cibao Formation and into the upper aquifer. The convex shape of the 10- and 20-foot contours towards the north in the upper aquifer was evidence of this overflow (plate 1). Renken and others (2002) indicated that deeper in the lower aquifer, ground-water flow is coastward along a circuitous path to the principal river drains. Ground-water levels ranged from 51 to 552 feet above mean sea level in the lower aquifer during the synoptic survey.

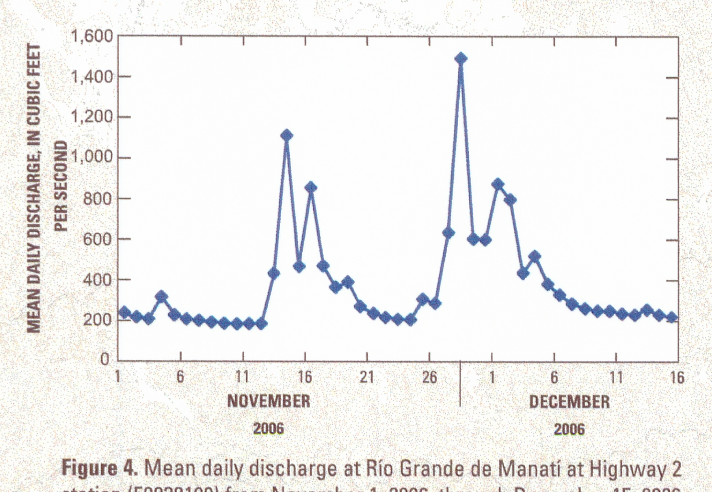


Figure 4. Mean daily discharge at Río Grande de Manatí at Highway 2 station (50038100) from November 1, 2006, through December 15, 2006.

Conclusions

The most significant changes in the potentiometric surface (pls. 1 and 2), compared to conditions in 1987 (Renken and Gómez-Gómez, 1994), were in the lower aquifer. Two large cones of depression are evident in the lower aquifer: one within the unconfined part of the aquifer north of the town of Florida, and, another within the confined part southwest of the town of Barceloneta. Compared to conditions in 1987 (Renken and Gómez- Gómez, 1994), ground-water levels in the cones of depression near Florida and Barceloneta indicated drawdowns of about 150 feet and 82 feet, respectively.

REFERENCES CITED

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Renken, R.A., and Gómez-Gómez, Fernando, 1994, Potentiometric surfaces of the upper and lower aquifers, north coast limestone aquifer system, Puerto Rico: U.S. Geological Survey Open-File Report 93-499, 16 p., 4 pls.

Renken, R.A., Ward, W.C., Gill, I.P, Gómez-Gómez, Fernando, Rodríguez-Martínez, Jesús, and others, 2002, Geology and hydrogeology of the Caribbean Islands Aquifer System of the Commonwealth of Puerto Rico and the U.S. Virgin Islands: U.S. Geological Survey Professional Paper 1419, 139 p., 5 pls.

Table 1. Accumulated monthly rainfall during 2006 at selected meteorological stations in the study area, and the 30-year monthly normal rainfall at the long-term National Weather Service station Manatí 2E.

[USGS, U.S. Geological Survey; NWS, National Weather Service; rainfall, in inches]

Station name	Station number	2006 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
USGS Rio Grande de Manatí at Hwy 2	(50038100)	4.46	0.96	1.91	8.27	6.9	4.28	6.56	4.38	6.8	9.05	6.59	3.3
USGS Raingage at San Agustin near Florida	(182329066341100)	6.7	0.81	5.44	8.2	7.02	4.04	4.31	4.24	3.94	7.68	10.9	3.63
NWS Manatí 2E	(665807)	7.19	1.01	2.09	7.74	9.64	4.22	5.84	5.95	4.05	8.77	8.41	3.68
NWS Manatí 2E normal	(665807)	4.05	3.33	2.77	4.9	6.42	2.94	3.65	4.9	5.57	6.17	6.36	5.77
NWS Manatí 2E departure from normal	(665807)	3.14	-2.32	-0.68	2.84	3.22	1.28	2.19	1.05	-1.52	2.60	2.05	-2.10

0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Base map U.S. Geological Survey Digital Raster Graphic files for the Arecibo, Barceloneta, Manatí, Utuado, Florida, and Ciales quadrangles, 1:20,000. Map scale modified to 1:40,000. The map is in the Lambert conformal conic projection. Puerto Rico Datum

POTENTIOMETRIC SURFACE OF THE UPPER AQUIFER OF THE NORTH COAST LIMESTONE AQUIFER SYSTEM IN THE ARECIBO-MANATÍ AREA, PUERTO RICO, NOVEMBER 27-DECEMBER 1, 2006

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